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RESEARCH PAPER

The Impact of Strain and Cage Type on the Welfare of Laying Hens in Different Seasons*

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Abstract

The aim of this study was to determine the effects of strain and cage type on the welfare of laying hens in commercial flocks over different seasons. A 2 x 2 x 3 factorial design was used to evaluate the effects of strain (white and brown layers) and cage type (conventional and enrichable battery cages) on the welfare of laying hens over three seasons (winter, spring and summer). The Welfare Quality® Assessment Protocol for Poultry was used to assess the welfare of laying hens. The strain and cage type significantly affected the welfare of the laying hens, which varied according to the season. Hens from the brown strain exhibited higher occurrences of FPD, keel bone abnormalities, and feather loss on the head and neck. White strains displayed a greater percentage of hens with abnormalities in the toe, comb, and beak, along with pecking wounds on the comb and extensive feather loss on the back, rump, and belly. A higher prevalence of comb abnormalities was observed in conventional cages. Hens in enrichable cages had higher rates of FPD, toe, comb and beak abnormalities, as well as pecking wounds on the comb and extensive feather loss. As a result, it was concluded that enrichable cages have a more adverse impact on the welfare of laying hens, with welfare losses in enrichable cages being more pronounced in brown hens compared to white hens and with interactions between strain and cage type varying seasonally.

Introduction

Research on the effects of enriched or cage-free systems on laying hen performance, health and welfare is ongoing. (Welfare Quality, 2009; Riber and Hinrichsen, 2016; Grafl et al., 2017). Over the past quarter of a century, there has been an increase in public and consumer interest in the welfare of laying hens (Hester, 2014). Because of their demands for high welfare standards for chickens, Directive 1999/74/EC on the protection of laying hens in the European Union came into force and was transposed into national law in Türkiye (Official Journal 29183 of 22 November 2014; as amended by Official Journal 31987 of 18 October 2022). Conventional cages, which severely restrict hens' freedom of movement, are banned. It also encourages the development of laying hen systems with higher welfare standards (Dawkins 2003).

Efforts to develop an industrial model for cage-free systems with outdoor access are still ongoing, and cage-free systems provide hens with the highest degree of freedom to move (Heerkens et al., 2015). However, challenges associated with egg production, cost efficiency, egg quality and animal health are described for these systems (Hartcher and Jones, 2017).On the other hand, even though enriched cages do not offer the same degree of freedom of movement to the hens, they have become a preferred housing system compared to conventional cages. This preference stems from increased comfort through features like claw trimming, nesting, perching and increased cage space (Hartcher and Jones, 2017;

Abrahamsson and Tauson, 1997). However, with the ban on conventional cages (the final deadline for which is 1 January 2026 in Turkey), the egg industry is facing a major cage system conversion, which will require significant economic resources. Enriched cages are gradually being purchased by poultry farms that are unable to convert their entire capacity at once. Enriched cages can be converted to enrichable cages by removing equipment such as perches, nests and claw-shortening devices, which can be integrated in a modular manner (Heflin et al., 2018; Alig et al., 2023). There is a limited amount of research on the effects of cage systems on the welfare of laying hens. In particular, there is a need for research to investigate the effects of enrichable cages on the welfare of laying hens. In addition, there is little research on how laying hen welfare is affected by cage type, strain and season, or the interactions between these factors.

Materials and Methods

Animals and Experiment Design

The study was conducted in four egg-producing poultry farms with two housing systems for laying hens in Afyonkarahisar. A 2 x 2 x 3 factorial design was used to investigate the effects of strain (white and brown laying hens) and cage type (conventional and enrichable battery cages) on the welfare of commercial laying hens during three seasons (winter, spring and summer). Super Nick and Nick Brown hens were housed in conventional cages (5 rows/5 or 6 tiers, and 8 or 9 birds per cage) and Hy-Line and Nick Brown hens were housed in enrichable cages (6 rows/6 or 7 tiers, and 18 or 19 birds per cage). Standard layer diets were fed to white (16-17% protein, 2600-2840 Kcal metabolic energy) and brown (15.8% protein, 2600 Kcal metabolic energy) strain laying hens. Animal care, indoor climate, air quality and lighting (16.5 L / 7.5 D) were controlled by automated systems. The Hy-Line birds were beak-trimmed with a hot blade at 9 days of age on the farm and the birds from the other 3 stains were beak-trimmed with infrared at 1 day of old in the hatchery. The birds were cared for and managed according to the breeder's guidelines (Hy-Line W-80 2016; Brown Nick 2016; Super Nick 2017). All layers had received a routine field vaccination programme. The study was approved by the Institutional Animal Ethics Committee of Afyon Kocatepe University (20 June 2017, No. AKUHADYEK-244-17). The results of this study on hen performance and mortality will be published in another paper (Kaba and Bozkurt, 2023).

Animal Welfare Assessment

The timing of the welfare assessments was planned according to the animal health and biosecurity policies and the production and marketing schedules of all the farms, so that the welfare assessments of the laying hens in the commercial flocks of the four farms could be carried out simultaneously. The welfare of laying hens in all flocks was assessed three times when they were between 36 and 56 weeks old. The welfare assessment was carried out on a total 969 laying hens in the winter season (December) the spring season (March) and the summer season (June) respectively. The sampling method and sample size per season measurement were based on the Welfare Quality (2009) standards and other on-farm welfare assessment methods to ensure reliable results for the welfare assessment of all flocks (Rodenburg et al., 2008; Casey-Trott et al., 2017). From each enrichable cage system, 5 enrichable cages were sampled. To obtain a representative average with a sample size comparable to the number of enrichable cages, 10 conventional cages were sampled from each of two other layer flocks kept in conventional cage systems. Thus, 30 cages were sampled in each season. Cages were randomly sampled from different rows (near the wall or in the centre of the poultry house) and from each level (top to bottom tiers) to ensure uniform sampling of different cage positions and within-cage conditions (Widowski et al., 2017). All birds in the sampled cages were scored. All hens in the sampled cages were carefully removed without frightening or injuring them and each was inspected and scored for head, foot and breast abnormalities and body feather damage. When the welfare assessment was repeated each season, samples were taken from other cages that had not been assessed in the previous season.

The method used to assess the welfare of laying hens was based on the welfare principles and criteria of The Welfare Quality® Assessment Protocol for Poultry (Welfare Quality, 2009). In addition, previous research on laying hen welfare was also considered (Heerkens et al., 2016; Grafl et al., 2017; Widowski et al., 2017). For the principle of good feeding, a resource-based measure was used; the feeder space per hen (cm/hen) was calculated by dividing the length of the feeders by the total number of hens in each cage (linear feeders extending in front of the cages). For good housing, the space allowance per hen (cm^2/hen) was determined by dividing the total cage area by the total number of hens in the cage.

Each hen was scored for the presence of foot pad dermatitis (FPD), keel bone abnormalities, eye pathology, toe damage, comb abnormalities and beak trimming and beak abnormalities as measures of good health. The condition of the foot pads for FPD was scored for the absence of injury and disease (score 0: no lesions; score 1: mild swelling, necrosis or chronic bumblefoot with no pain and small superficial wounds ≤0.5 cm in diameter. The hens' toes (score 0: no signs of toe damage, score 1: toe damage, deformity or malformation), and eyes (score 0: no signs of eye pathology, score 1: swelling, lesions on the skin around the eye, eye discharge, and closed eye) were examined and the pathology and abnormalities observed were scored. The breast region of the hens was carefully observed and fingers were run along the side and over the keel bone to examine it. The condition of the keel bone was then scored (score 0: no deformities or fractures, score 1: deviation, fracture, collapse, deformities or thickened areas present on the sternum or keel bone). The beaks of the hens were examined and abnormalities associated with beak trimming were scored (score 0: no abnormalities, score 1: beak not trimmed or with mild to moderate abnormalities, score 2: severe trimming, obvious abnormalities) as a measure of the absence of pain caused by management procedures. Abnormalities of the hens' comb were scored (score 0: no abnormalities, score 1: slightly pale colour or slight discolouration on comb, score 2: bruising or large areas of different colour on comb). Signs potentially associated with aggressive pecking on the comb of the hens (as a welfare criterion and expression of social behaviors) were scored (score 0: no evidence of pecking wounds, score 1: few pecking wounds or scars less than 3, score 2: numerous wounds, new or healing wounds more than 3). As a measure of the same welfare criteria, the hens were assessed and scored separately for feather loss and feather damage in three body parts: head-neck, back-rump and belly and around the cloaca (score 0: complete feather cover and no feather loss, score 1: moderate feather damage or loss, at least one bare skin area <5 cm in diameter, score 2: excessive feather damage or loss, at least one bare skin area ≥5 cm in diameter).

Statistical analysis

Two-way analysis of variance (ANOVA) was used to analyse the data collected in terms of feeder space and cage area per bird for each season. The chi-squared test was used to evaluate the data related to the occurrence of footpad dermatitis (FPD), keel bone abnormalities, eye pathology, toe damage, comb abnormalities, beak trimming and beak abnormalities, comb pecking wounds and feather damage in each season. Data analysis was performed using the SPSS version 21.0 for Windows. Differences were considered statistically significant when the significance level was less than 0.05.

RESULTS

The results for feeder space and space allowance are shown in Table 1. The effect of stain on feeder space was found to be significant in the spring season and overall (P<0.05, P<0.001); however, the effect of cage type was not significant in any of the seasons. The feeder space was smaller for white-strain hens, and a significant interaction between strain and cage type was observed for the feeder space. This interaction was particularly notable during the summer season (P<0.01). Strain and cage type considerably impacted the space allowance in the cages (P<0.001). Space allowance was influenced by strain in the spring and in overall (P < 0.05, P < 0.001). The effect of cage type on space allowance was insignificant in seasonal groups but it was significant in overall (P<0.001). Among the different strain flocks, the allocated living area per hen was greater for brown-layer hens. Notably, during the spring and summer, the cage area provided for brown hens was significantly larger than white hens (P < 0.01), with a difference of 74 cm^2 favoring brown hens. Enrichable cages also provided more space per bird than conventional cages, with an average of 39-52 cm^2 more cage area in enrichable cages. The interaction between strain and cage type was particularly notable during the summer, with similar space allowances in both cage types for brown hens (474.20 and 474.05 cm^2). In contrast, the space allowances for white hens housed in conventional and enrichable cages were 377.03 and 461.66 cm^2, respectively. White and brown laying hens housed in enrichable cages had similar feeder space (7.74 and 8.01 cm), whereas, in conventional cages, there was a significant difference between these values between two strains of layers (6.61 and 8.32 cm).

The results related to the effects of strain and cage type on FPD, toe damage, keel bone abnormalities and eye pathologies in different seasons are given in Table 2. The rate of hens with PFD was affected by strain in summer and cage type in winter and spring. Toe damage was significantly influenced by strain in winter and spring (P<0.01) and by cage type in spring (P<0.05). Regardless of season, both FPD and toe damage were generally affected by strain and cage type (P<0.05, P<0.01, P<0.001). The effect of strain and cage type on eye pathologies was not significant in any season. Keel bone abnormality was affected by strain in spring and summer (P< 0.01), whereas cage type had no significant effect.

The results concerning the effects of strain and cage type on comb and beak abnormalities and comb peck wounds in different seasons are given in Table 3. Comb abnormalities were significantly influenced by strain in winter (P<0.001) and by cage type in spring (P<0.05). However, regardless of the seasonal effect, strain and cage type influenced comb abnormality (P<0.05, P<0.01). Strain significantly affected beak abnormality in spring and summer (P<0.001), while cage type didn't show any significant effects during across the seasons. Disregarding the seasonal effect, beak abnormality was only significantly (P<0.001) influenced by strain. Strain significantly influenced comb pecking wounds in all three seasons (P<0.001, P<0.05). Although the within-season effects are insignificant, the overall assessment of all seasons showed that strain and cage type influenced comb pecking wounds (P<0.05).

Table 4 shows the results of the effects of strain and cage type on feather damage and feather loss on three individual body parts in different seasons. Head and neck feather damage was significantly affected by strain in all seasons (P<0.05, P<0.01) and by cage type in spring and summer (P<0.05, P<0.001). The effects of strain (P<0.001) and cage type (P<0.01, P<0.001) on back-rump feather damage were significant in winter and summer. Belly feather damage was strongly influenced by strain in winter and summer (P<0.05), and the effects of cage type were significant only in summer (P<0.05). In the overall assessment, regardless of season, plumage damage was significantly (P<0.001) influenced by strain for back-rump and head-neck, and by cage type for back-neck and belly (around the cloaca) (P<0.001, P<0.01).

DISCUSSION

In this study, feeder space per bird was significantly influenced by strain and the interactions between strain and cage type. White and brown laying hens housed in enrichable cages had similar feeder space (7.74 and 8.01 cm), whereas, in conventional cages, there was a significant difference between these values (6.61 and 8.32 cm). Feeder space in all experimental groups was therefore less than required by EU legislation (10 cm per hen), and was lowest for the conventionally housed white hens in particular (Council Directive 1999/74/EC) (Council Directive, 1999). In terms of the principle of good feeding, insufficient feeder space for all birds can lead to detrimental outcomes due to increased competition between hens for access to feed (Thogerson et al., 2009). The legal cage area requirement (750 cm² per hen) was not met by both white and brown hens in conventional and enrichable cages. Brown hens in enrichable cages (499.77 cm²/hen) were found to have less space than white hens (514.33 cm²), especially in summer. These results showed that cage overcrowding increased for the larger brown hens in the enrichable cages. Mortality was already higher in enrichable cages, and the cumulative weekly mortality rate of white and brown breeds housed in enrichable cages was 0.34% and 0.36%, respectively (Kaba and Bozkurt, 2023).

Hens of the White strain had a higher prevalence of abnormalities in the toe, beak and comb than those of the Brown strain. Toe and comb abnormalities were more pronounced in winter, while the prevalence of beak abnormalities was higher in spring and summer. The hot blade beak trimming method and applicator errors in the Hy-Line birds may be responsible for the higher incidence of beak abnormalities in the White strain hens, as the beaks of all the other hens were trimmed by infrared trimming in the hatchery. More consistent beak lengths and fewer abnormalities, such as cracks, asymmetric regrowth and blisters were reported in birds whose beaks were trimmed using infrared compared to birds whose beaks were trimmed using a hot blade (Carruthers et al., 2012; Glatz and Underwood, 2020). The prevalence of comb peck wounds was highest in white strain hens across all seasons, suggesting a higher incidence of aggressive pecking in white hens. White strain hens with a higher prevalence of toe abnormalities are thought to be more reactive to stressors and experience more panic, resulting in damage to their toes and claws as they become entangled in the grids on the cage floor (Fraisse and Cockrem, 2006; Janczak and Riber, 2015). The absence of wounds is an important welfare criterion (Grafl et al., 2017), as it is essential for the health and welfare of laying hens. Some studies have suggested that anxiety levels may vary between strains and that the acquisition of anxiety may be reduced or enhanced by the experience of birds in commercial conditions (Hocking et al., 2001).

Foot pad dermatitis (FPD) was common in all hens tested (no birds were scored 3). However, it was particularly high in the brown flocks. Overall, the proportion of brown layer hens with lesions on the foot pads was 34.2 % and this rate increased to 54.4 % during the summer months. The significant effect of strain on FPD was also reported by Niebuhr et al. (2009). It may also have been influenced by the fact that the brown hens had a heavier body weight than the white hens. In this study, the smaller amount of space available per brown hen in the enrichable cages may also have contributed to this condition (Niebuhr et al., 2009). FPD lesions can appear as hyperkeratosis and dermatitis on the foot pads, usually due to prolonged ground contact by the birds. These painful lesions, especially in the case of advanced lesions, are detrimental to the health and welfare of the birds (Abrahamsson and Tauson, 1997; Riber and Hinrichsen et al., 2016; Rørvang et al., 2019; Oliveira et al., 2019). In conventional cages, the percentage of laying hens with FPD lesions was significantly higher only in winter (17.1%) than in enrichable cages. Similarly, Grafl et al (2017) reported poorer feather condition and increased skin and footpad lesions in hens during the winter months. The lower rate of footpad lesions in conventional cages may be due to the restrained behavior of the hens due to the limited cage space (Hartcher and Jones, 2017). In spring and summer, the rate of hens with FPD is higher in enrichable cages (24.6 and 2.9 % higher). Particularly in spring, the prevalence of FPD lesions (61.5%), toes (34.8%), comb abnormalities (46%) and comb peck

Table 1. Effect of strain and cage type on feeder space and space allowance per hen in the cages in different seasons

			Winter			Spring			Summer			General	
			Feeder space (cm/hen)	Space allowance (cm^2/hen)		Feeder space (cm/hen)	Space allowance (cm^2/hen)		Feeder space (cm/hen)	Space allowance (cm^2/hen)		Feeder space (cm/hen)	Space allowance (cm^2/hen)
Stain	Cage type	n	Mean	Mean		Mean	Mean		Mean	Mean	n	Mean	Mean
White		15	6.74	391.32	15	6.94	402.89	15	7.25	421.51	45	6.97	405.24
Brown		15	7.75	449.59	15	8.24	477.43	15	8.55	495.43	45	8.18	474.15
	Conventional	20	7.15	407.48	20	7.52	428.17	20	7.74	441.19	60	7.47	425.61
	Enrichable	10	7.44	446.41	10	7.74	464.14	10	8.22	493.02	30	7.80	467.86
SEM			0.234	13.739		0.207	12.291		0.228	13.323		0.129	7.599
R^2			0.181	0.216		0.361	0.373		0.418	0.441		0.286	0.310
P value													
Strain			0.053^{-}	0.055^{-}		0.018*	0.021*		0.068^{-}	0.079^{-}		0.000***	0.001***
Cage			0.539^{-}	0.168^{-}		0.594^{-}	0.155^{-}		0.305^{-}	0.063^{-}		0.204^{-}	0.007**
Strain x Cage			0.704^{-}	0.743^{-}		0.081^{-}	0.096^{-}		0.008**	0.009**		0.005**	0.007**

*:P<0.05, **:P<0.01, ***:P<0.001 -: Non significant

Table 2. Effect of strain and cage type on FPD, toe damage and, keel bone abnormalities and eye pathologies in different seasons

				Winter		Spring		Summer		General	
Measures	Strain	Cage type	χ^2	Score 0	Score 1	Score 0	Score 1	Score 0	Score 1	Score 0	Score 1
FPD	White			86.5	13.5	55.9	44.1	82.3	17.7	75.2	24.8
	Brown			87.0	13.0	45.6	54.4	65.4	34.6	65.8	34.2
	General			86.8	13.2	50.8	49.2	74.0	26.0	70.6	29.4
			P	0.902^{-}		0.066^{-}		0.001***		0.001***	
		Conventional		82.9	17.1	63.1	36.9	75.5	24.5	73.8	26.2
		Enrichable		90.4	9.6	38.5	61.5	72.6	27.4	67.5	32.5
		General		86.8	13.2	50.8	49.2	74.0	26.0	70.6	29.4
			P	0.046*		0.000***		0.551^{-}		0.031*	
	White			84.2	15.8	63.4	36.6	75.6	24.4	74.6	25.4
Toe	Brown			94.2	5.8	78.8	21.2	82.4	17.6	85.0	15.0
	General			88.9	11.1	71.0	29.0	78.9	21.1	79.7	20.3
			P	0.004**		0.002**		0.135^{-}		0.000***	
		Conventional		91.8	8.2	76.9	23.1	81.8	18.2	83.4	16.6
		Enrichable		86.2	13.8	65.2	34.8	76.2	23.8	76.0	24.0
		General		88.9	11.1	71.0	29.0	78.9	21.1	79.7	20.3
			P	0.111^{-}		0.021*		0.222^{-}		0.004**	
Eye	White			97.7	2.3	96.9	3.1	98.2	1.8	97.6	2.4
	Brown			99.4	0.6	92.5	7.5	97.5	2.5	96.4	3.6
	General			98.5	1.5	94.7	5.3	97.8	2.2	97.0	3.0
			P	0.216^{-}		0.079^{-}		0.672^{-}		0.283^{-}	
		Conventional		97.5	2.5	93.1	6.9	97.5	2.5	96.0	4.0
		Enrichable		99.4	0.6	96.3	3.7	98.2	1.8	98.0	2.0
		Cage type total		98.5	1.5	94.7	5.3	97.8	2.2	97.0	3.0
			P	0.157^{-}		0.208^{-}		0.672^{-}		0.075^{-}	
Keel bone	White			96.5	3.5	96.3	3.7	99.4	0.6	97.4	2.6
	Brown			98.7	1.3	88.1	11.9	93.7	6.3	93.4	6.6
	General			97.5	2.5	92.2	7.8	96.6	3.4	95.5	4.5
			P	0.199^{-}		0.006**		0.005**		0.003**	
		Conventional		96.8	3.2	90.6	9.4	95.6	4.4	94.3	5.7
		Enrichable		98.2	1.8	93.8	6.2	97.6	2.4	96.5	3.5
		General		97.5	2.5	92.2	7.8	96.6	3.4	95.5	4.5
			P	0.426^{-}		0.290^{-}		0.331^{-}		0.099^{-}	

*:P<0.05, **:P<0.01, ***:P<0.001, -: Non significant, **FPD**: Food pad dermatitis

Table 3. Effect of strain and cage type on comb and beak abnormalities and comb pecking wounds in different seasons.

				Winter			Spring			Summer			General		
Measures	Strain	Cage type	χ^2	Score 0	Score 1	Score 2	Score 0	Score 1	Score 2	Score 0	Score 1	Score 2	Score 0	Score 1	Score 2
	White			67.8	25.2	7.0	52.8	42.9	4.3	60.4	28.6	11.0	60.5	32.0	7.5
Comb	Brown			85.1	13.0	1.9	56.9	35.0	8.1	65.5	27.0	7.5	68.9	25.2	5.9
	General			76.0	19.4	4.6	54.8	38.9	6.3	62.8	27.9	9.3	64.6	28.7	6.7
			P		0.001***			0.187-			0.491-			0.023*	
		Conventional		79.1	15.8	5.1	59.4	31.8	8.8	67.3	23.9	8.8	68.6	23.9	7.5
		Enrichable		73.0	22.8	4.2	50.3	46.0	3.7	58.5	31.7	9.8	60.8	33.3	5.9
		General		76.0	19.4	4.6	54.8	38.9	6.3	62.8	27.9	9.3	64.6	28.7	6.7
			P		0.281-			0.014*			0.243-			0.005**	
Beak	White			28.7	39.8	31.5	17.4	46.6	36.0	25.6	36.0	38.4	24.0	40.7	35.3
	Brown			35.1	31.2	33.8	53.1	33.1	13.8	49.7	37.1	13.2	46.1	33.8	20.1
	General			31.7	35.7	32.6	35.2	39.9	24.9	37.5	36.5	26.0	34.8	37.4	27.8
			P		0.241-			0.000***			0.000***			0.000***	
		Conventional		34.8	34.2	31.0	38.8	35.6	25.6	37.7	35.2	27.0	37.1	35.0	27.9
		Enrichable		28.7	37.1	34.1	31.7	44.1	24.2	37.2	37.8	25.0	32.5	39.6	27.8
		General		31.7	35.7	32.6	35.2	39.9	24.9	37.5	36.5	26.0	34.8	37.4	27.9
			P		0.501-			0.266-			0.868-			0.240-	
Comb	White			38.6	49.1	12.3	62.7	34.8	2.5	53.0	27.5	19.5	51.2	37.3	11.5
pecking	Brown			70.8	26.6	2.6	48.1	44.4	7.5	49.7	39.6	10.7	56.0	37.0	7.0
wounds	General			53.8	38.5	7.7	55.5	39.5	5.0	51.4	33.4	15.2	53.6	37.2	9.2
			P		0.000***			0.011*			0.019*			0.041*	
		Conventional		58.9	33.5	7.6	61.9	33.1	5.0	54.1	32.7	13.2	58.3	33.1	8.6
		Enrichable		49.1	43.1	7.8	49.0	46.0	5.0	48.8	34.1	17.1	49.0	41.0	10.0
		General		53.8	38.5	7.7	55.5	39.5	5.0	51.4	33.4	15.2	53.5	37.2	9.3
			P		0.185-			0.057-			0.525-			0.014*	

*:P<0.05, **:P<0.01, ***:P<0.001, -: Non significant

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Table 4. Effect of strain and cage type on plumage damage on three individual body parts in different seasons

				Winter			Spring			Summer			General		
Measures	Strain	Cage type	χ^2	Score 0	Score 1	Score 2	Score 0	Score 1	Score 2	Score 0	Score 1	Score 2	Score 0	Score 1	Score 2
Head-neck	White			88.9	11.1	0.0	58.4	26.1	15.5	54.3	29.9	15.9	67.5	22.2	10.3
	Brown			79.2	19.5	1.3	45.0	38.1	16.9	36.5	47.2	16.4	53.3	35.1	11.6
	General			84.3	15.1	0.6	51.7	32.1	16.2	45.5	38.4	16.1	60.6	28.5	10.9
			P		0.032^{*}			0.039^{*}			0.003^{**}			0.000^{***}	
		Conventional		82.9	17.1	0.0	58.8	30.0	11.3	43.4	31.4	25.2	61.6	26.2	12.2
		Enrichable		85.6	13.2	1.2	44.7	34.2	21.1	47.6	45.1	7.3	59.6	30.7	9.8
		General		84.3	15.1	0.6	51.7	32.1	16.2	45.5	38.4	16.1	60.6	28.5	10.9
			P		0.248^{-}			0.016^{*}			0.000^{***}			0.206^{-}	
Back-rump	White			96.5	3.5	0.0	59.0	24.8	16.1	39.6	33.5	26.8	65.5	20.4	14.1
	Brown			81.8	17.5	0.6	50.6	34.4	15.0	48.4	46.5	5.0	60.0	33.0	7.0
	General			89.5	10.2	0.3	54.8	29.6	15.6	44.0	39.9	16.1	62.8	26.5	10.6
			P		0.000^{***}			0.169^{-}			0.000^{***}			0.000^{***}	
		Conventional		96.5	4.4	0.0	56.9	25.0	18.1	31.4	42.1	26.4	61.2	23.9	14.9
		Enrichable		83.8	15.6	0.6	52.8	34.2	13.0	56.1	37.8	6.1	64.4	29.1	6.5
		General		89.5	10.2	0.3	54.8	29.6	15.6	44.0	39.9	16.1	62.8	26.5	10.6
			P		0.002^{**}			0.146^{-}			0.000^{***}			0.000^{***}	
Belly	White			98.8	1.2	0.0	64.6	26.1	9.3	65.2	25.6	9.1	76.6	17.3	6.0
	Brown			92.9	6.5	0.6	68.8	24.4	6.9	76.7	22.0	1.3	79.3	17.8	3.0
	General			96.0	3.7	0.3	66.7	25.2	8.1	70.9	23.8	5.3	77.9	17.5	4.5
			P		0.022^{*}			0.640^{-}			0.003^{**}			0.070^{-}	
		Conventional		98.1	1.9	0.0	71.9	19.4	8.8	76.7	20.8	2.5	82.2	14.0	3.8
		Enrichable		94.0	5.4	0.6	61.5	31.1	7.5	65.2	26.8	7.9	73.8	20.9	5.3
		General		96.0	3.7	0.3	66.7	25.2	8.1	70.9	23.8	5.3	77.9	17.5	4.5
			P		0.152^{-}			0.055^{-}			0.027^{*}			0.007^{**}	

*:P<0.05, **:P<0.01, ***:P<0.001, -: Non significant wounds (41%) were higher in the hens housed in enrichable cages. In addition, the prevalence of keel bone and eye abnormalities was slightly higher in these hens in all seasons, but the differences between cage types were not statistically significant. These results were consistent with the report of Niebuhr et al. (2009), who reported a positive correlation between stocking density and FPD but these results contrasted were contrasted with the findings of Hester (2014).

These results are consistent with the report of Niebuhr et al. (2009), who reported a positive correlation between stocking density and FPD, but contrast with the findings of Hester (2014). The results of this study regarding foot and toe problems may be related to the lack of access to perches in enrichable cages, as perches contribute to the health of foot pads, toes and claws (Riber and Hinrichsen, 2016). However, the proportion of hens with keel bone and eye abnormalities was lower in enrichable cages than in conventional cages. This finding contradicts Riber and Hinrichsen (2016), who reported a higher prevalence of keel bone fractures in enriched cages. Keel bone fractures and deformities significantly restrict the behavior of commercial laying hens and compromise their welfare (Stratmann et al., 2015; Riber and Hinrichsen, 2016). The high incidence of both FPD and foot pad deformities in Brown strain hens suggests a possible link between the development of these two traits. This argument is supported by Heerkens et al. (2015), who reported a positive correlation between sternal fracture prevalence of sternal fractures and foot pad lesions. Already, in spring, the proportion of brown strain hens with keel bone abnormalities (11.9% and 6.3%) and comb pecking wounds was higher in spring (44.4 and 7.5% for score 1 and 2) than in summer (39.6 and 10.7% for score 1 and).Hens housed in conventional cages had a higher prevalence of comb abnormalities (7.5 %), but fewer toe abnormalities and pecking comb lesions than those housed in enrichable cages. Traumatic damage and deformities to the keel bones can cause to acute or chronic pain and affect the welfare of the laying hens (Fleming et al., 2004; Nasr et al., 2012; Riber and Hinrichsen, 2016). Riber and Hinrichsen (2016) also reported that keel bone deformities in laying hens may have contributed to hens spending more time lying down and standing, resulting in increased footpad lesions.

The white strains showed a more moderate degree of feather loss in the head-neck area than the brown strains. However, the white strains were the most likely to show severe feather loss on the back rump. Particularly in the summer, 26.8% of white strain hens showed an excessive feather loss of feathers around the back rump and the belly (prevalence of moderate and severe feather loss were 25.6% and 9.1%, respectively). In conventional cages, white strain hens had the least space allowance per bird, which may explain the increased proportion of birds with severe feather loss. This is supported by Widowski et al. (2017), who reported that laying hens with lower space allowances tended to have poorer feather conditions. In addition, it has been suggested that these findings on feather loss may be related to stress responses and fear. A positive relationship between fear and pecking behavior has been reported (Rodenburg et al., 2004; Heerkens et al., 2016).In all seasonal periods, moderate and severe feather loss in the head-neck region was higher in brown strain hens, but the strain differences for these traits were more pronounced in the summer season (47.2% and 16.4% for scores 1 and 2). The percentage of brown strain hens with moderate and severe feather loss in the back-rump area was higher than that of the white strains in both winter (17.5% and 0.6%) and summer (46.5% and 5.1%). Feather damage around the cloaca area was less pronounced in brown hens and was only higher in winter (6.5% and 0.6%) compared to white strains. Overall, these feather damage findings could also be related to a genetic predisposition to severe feather pecking behaviour (Rodenburg et al., 2004), group size (Rørvang et al., 2019) or other stress-related risk factors (De Haas et al., 2013). For the hens in conventional cages, feather loss in the head-neck and belly and around the cloaca areas was not common; however, the percentage of hens with moderate and severe feather damage in the back-rump area was higher compared to those in enrichable cages (42.1% and 26.4% for Scores 1 and 2, respectively).

Compared to conventional cages, the percentage of hens with moderate or severe feather loss was higher enrichable cages in spring and summer for the head-neck area (34.2% and 45.1%, and 21.1% and 7.3%, respectively), in winter for the back-rump area (15.6 and 0.6%), and in summer for the belly (26.8 and 7.9%) in enrichable cages. Feather pecking behavior is abnormal in stressed hens (De Haas et al., 2013). This study suggests that enriched cages provide hens with more behavioural opportunities by increasing the amount of space available to the hens. However, it has been noted that enriched or enrichable cages might only partially accommodate the behavioral repertoire of the hens (Hartcher and Jones, 2017). These results suggest that the group size in enrichable cages is another important significant factor. Widowski et al. (2017) reported higher cumulative mortality rates in furnished cages that housing larger groups. The relationship between reduced feather condition and lower stocking densities has not been clearly established (Grafl et al., 2017; Widowski et al., 2017). However, the feather loss results suggest that brown strain hens in enrichable cages may experience greater stress, and their welfare may be lower than white strain hens under the same conditions (Rodenburg et al., 2008). In general, it was determined that feather damage was higher in both conventional and enrichable cages. Feather pecking refers to hens pecking and pulling the feathers of others, posing a risk of cannibalism in the poultry industry, which threatens animal welfare, health, and production performance (Hartcher and Jones, 2017). However, the aging of the animals from winter to summer may have influenced the welfare characteristics studied, as the same experimental flocks were subjected to repeated welfare assessments during the winter, spring and summer seasons. Riber and Hinrichsen (2016) reported that the prevalence of sternal fractures increases with the age of laying hens. New research is needed to more clearly separate the factors of age and seasonality.

CONCLUSION

The strain and cage type significantly affected the welfare of the laying hens, which varied according to the season. Significant differences in scape allowance per hen in the cage, toe and beak abnormalities, keel bone problems comb peck wounds and feather damage were observed between white and brown strains for at least two seasons. Brown strain hens had more FPD, keel bone abnormalities and feather loss on the head and neck. The white strains had a higher percentage of hens with toe, comb and beak abnormalities, pecking wounds on the comb, and extensive feather loss on the back of the rump and belly. Hens in conventional cages had a higher incidence of comb abnormalities. Hens in enrichable cages had a higher proportion of hens with FPD, abnormalities in the toe, comb and beak and pecking wounds on the comb and extensive feather damage on the back rump and belly. In conclusion, enrichable cages had a more negative effect on the welfare of laying hens. The welfare losses in enrichable cages were more pronounced in brown hens than in white hens housed in the same cages, and the interactions between strain and cage type varied from season to season.

Conflict of interest: The authors declare that there are no actual, potential, or perceived conflicts of interest in this article.

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Author Contributions

First Author: Data Collection, Data Analysis and/or Interpretation, Literature Search, Writing Manuscript

Second Author: Conceptualization, Consultation, Data Analysis and/or Interpretation, Literature Search, Writing Manuscript, Critical Review

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